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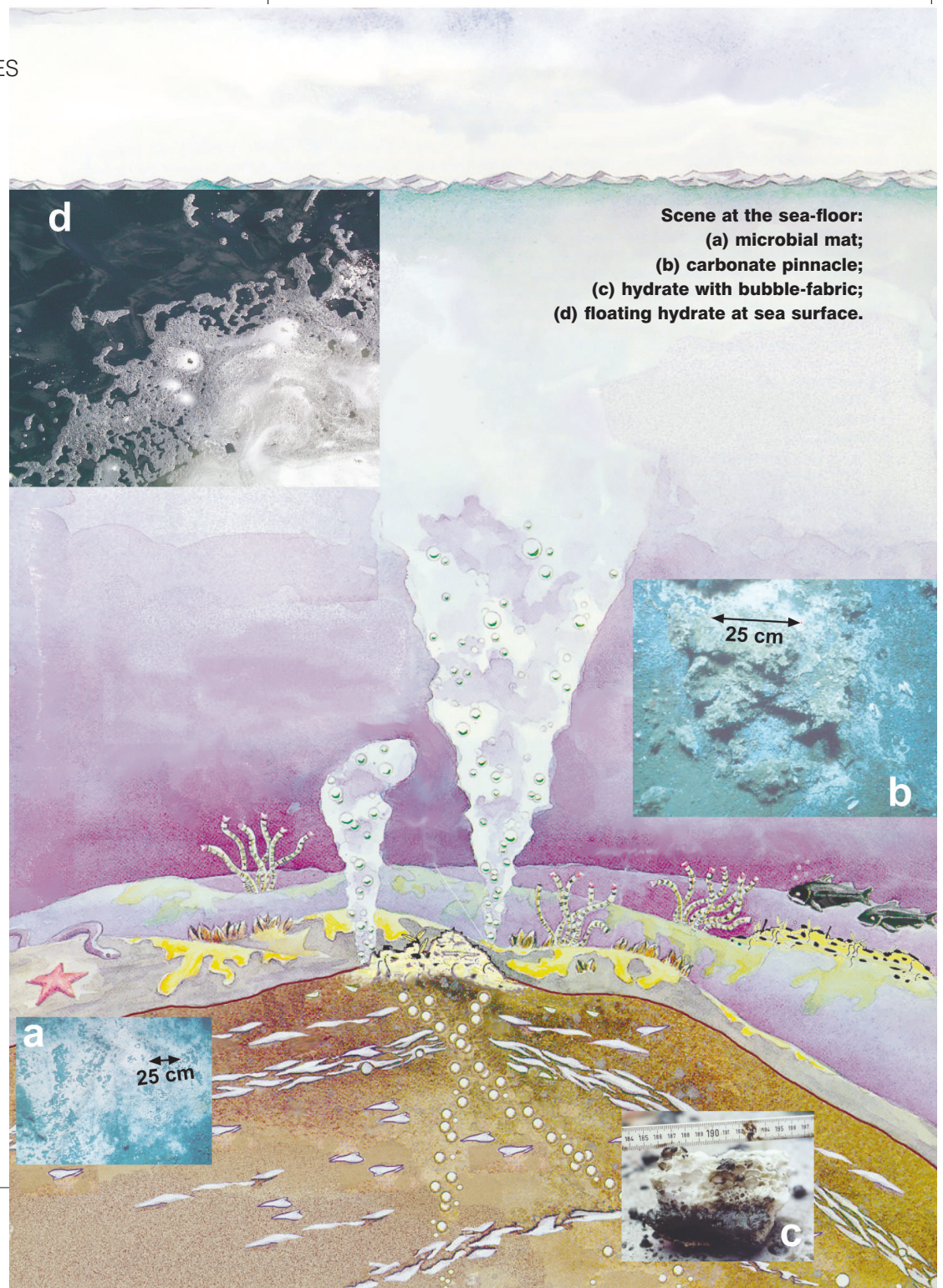
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PHYSICAL: METHANE HYDRATES

Not only can large chunks of hydrate vented from the sea-floor add to climate change, they can effect biological and other activities. Researchers have been trying to identify hydrate dynamics by deploying the Canadian ROPOS ROV. **Dr Peter Linke*** explains

It is generally recognised that destabilisation of gas hydrates and the resulting release of methane may be one of the most powerful trigger mechanisms on past abrupt climatic changes of the earth system. However, in climate research the release of methane from gas hydrates has hardly been considered in model calculations since little information exists concerning interfacial fluxes and biogeochemical turnover of methane in sediments hosting hydrate deposits.

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Hydrate vents — a window to the deep biosphere?

Gas hydrates location

Gas hydrates are solid compounds of an ice-like crystalline structure which host low molecular weight gases, such as CH₄, CO₂, H₂S, and short-chain hydrocarbons in cages formed by water molecules. Marine gas hydrates are common in sediments deposited at high latitude continental shelves and at the slope and rise of continental margins with high bioproductivity.

High biological production provides the organic matter buried in the sediment, which during early diagenesis and after exhausting oxygen, sulfate and other electron acceptors, eventually generates methane through fermentative decomposition and/or microbial carbonate reduction.

As a result gas hydrates usually occur at depths well below the sediment surface because either methane is not generated at shallow depths or is rapidly oxidized by microbial consortia using pore water sulfate as oxidizing agent. Contrary to this usual situation, methane gas hydrates are being discovered with increasing frequency in near-surface sediments at continental margins.

At these settings deeply generated methane is transported to and expelled at the seafloor by gas, mud, and/or fluid advection. At active margins advection is driven by convergent plate tectonics and at passive margins by over-pressured sediment-loaded strata. Such a continuous and vigorous supply of methane from the subsurface sustains the formation of methane hydrates or hydrates. These were recovered from the seafloor at Hydrate Ridge. This tectonic unit of the Cascadia convergent margin has become one of the prime study sites of marine gas hydrates since its discovery in 1996.

TECFLUX programme

This discovery initiated the establishment of the international TECFLUX programme (TECtonically induced FLUXes)

which addresses geophysical, biogeochemical, and hydrographic processes associated with fluid venting from the Cascadia convergent margin, specifically the processes resulting from the methane hydrate dynamics at Hydrate Ridge.

Expeditions aboard RV *Atlantis* and RV *Sonne* were jointly planned, coordinated and carried out by the GEOMAR Research Center for Marine Geosciences at Kiel and the College of Ocean and Atmospheric Sciences of Oregon State University, Corvallis, with investigator groups from the following institutions: Scripps Institution of Oceanography, La Jolla; Large Lake Observatory, Duluth; Humboldt State University, Eureka; University of Southern California, Los Angeles; Monterey Bay Aquarium Research Institute, Moss Landing; University of Victoria, Victoria; Geological Survey of Japan, Tsukuba; Max-Planck Institute for Marine Microbiology, Bremen; Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover; Technische Universität, Berlin, and Geoforschungszentrum, Potsdam.

Fault pattern

The fault pattern on Hydrate Ridge, generated by subduction of the Juan de Fuca Plate underneath the North American Plate, is well-known and related to the evolution and growth of accretionary tectonics of the Cascadia convergent margin. The faults extend through the accreted sediments to below the gas hydrate phase transition. At depth, they tap a fluid reservoir, which contains free methane.

The faults serve as conduits and channel methane up to the sea-floor where it either escapes into the water column or forms secondary gas hydrates. The secondary sea-floor hydrates are very porous and less dense than seawater. As the layers grow downward towards the rising stream of methane, their buoyancy eventually exceeds the

lithostatic loading by sediments and chunks of hydrate detach and float to the sea surface.

Hydrate float development

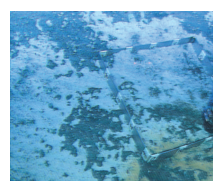
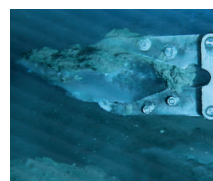
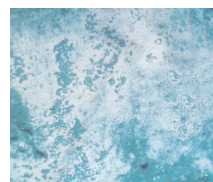
The scenario for the development of hydrate floats is based on high-resolution small-scale mapping of vent fields and hydrate exposures and on sampling of the complete gas hydrate-pore water-sediment system which were the objectives of *Sonne* expeditions.

In piecing together this scenario, which represents an efficient mechanism for this greenhouse gas to escape into the atmosphere, extensive new observations from the ROV ROPOS system and sea-floor video-surveys and sampling from aboard RV *Sonne* were required. In summer 2000, the chartered ROV system, operated by the Canadian Scientific Submersible Facility (CSSF), accomplished the following tasks during *Sonne* cruise 148:

- Detailed bottom surveys and sampling
- Precise deployment and recovery of time-lapse cameras at gas outlets
- Triggering a bank of Niskin water bottles mounted on the ROV in specific locations
- In-situ experiments with natural gas hydrates
- Re-positioning Landers to seal the chamber
- Recovery of lost instruments.

Some results from the TECFLUX programme demonstrate that gas hydrate in surface sediments of the Cascadia accretionary margin contains new detailed information on the dynamics of methane supply, of hydrate formation and dissociation, and of the variability of physical and chemical hydrate properties.

Of these, the highly porous fabric combined with altered pore water, which apparently is trapped in the hydrate interstices, has the most far-reaching implications. As one of the consequences of the porous fabric, the bulk density of natural hydrates



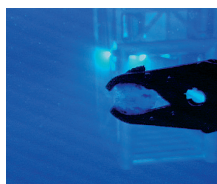
The thumbnail illustrations document some of the tasks performed by ROPOS during the 'Sonne' cruise 148

PHYSICAL: METHANE HYDRATES

is considerably lower than that of pure, theoretical and experimentally produced hydrates. The lower bulk density is responsible for the efficient transfer of methane from the seafloor to the surface ocean and hence into the atmosphere via floating chunks of hydrate. The implications of low bulk density, if it persists also downward throughout the sediment column, for slope stability and seismic velocity structure, are profound.

Driving force

There is also a largely unknown series of chemical reactions possible when hydrates form through rapid supply of gaseous methane, as with the vent systems encountered at Hydrate Ridge. By consuming most, if not all, of the water available in the sediment pore space, hydrate formation may cause interstitial brines to precipitate transient solid phases, which remain enclosed in the porous fabric. Such reactions are, currently, entirely hypothetical, but future sampling of



hydrates, designed to preserve in-situ conditions for the study of and experiments with gas hydrates, are essential in order to advance our knowledge.

The newly recognised methane-oxidizing bacterial consortium which populates the exposures of hydrate and hydrate vents at the Hydrate Ridge provides the driving force for the exceedingly high benthic biological activity which is evident in the sediment oxygen consumption. The microbial assemblages and their role in this activity are only beginning to be understood.

Such high microbial activity is fueled by the discharge of methane from destabilised hydrate at the sea-floor or from below, if faults open up pathways for free methane to escape upwards from below the hydrate stability zone. Hence, accretionary tectonics provide unique settings through continuous supply of methane, for AMO-communities (anaerobic methane oxidation) to develop. Thus processes at hydrate vents may provide a window to the deep

biosphere. The methane supply rates, however, vary by many orders of magnitude spatially and temporally, which highlights the need for implementing of sea-floor observatories at gas hydrate sites.

Acknowledgements

The expedition and programme of TECFLUX were financed in Germany by the Federal Ministry of Science and Technology, Bonn. Project review and scheduling of the Sonne Cruises were handled efficiently by the Projektträger Jülich.

The ROPOS crew demonstrated that the ROV system is a valuable and reliable work tool which ideally supplements the existing instrumentation on a research vessel like *Sonne*. The Reedereigemeinschaft Forschungsschiffahrt, RF Bremen, provided technical support on the vessel in order to accommodate the variety of technological, electronic, and navigational challenges required for the complex seagoing operations.

A description of the ROPOS system accompanies this article.

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